Intensive Care Med (2011) 37:891–892
DOI 10.1007/s00134-011-2193-5

Thomas Thaler
Alain Rudiger

How to diagnose ECG artifacts due to electrode misplacements

Accepted: 4 January 2011
Published online: 25 February 2011

Dear Editor,

The 12-lead electrocardiogram (ECG) is essential for detection of arrhythmias and acute coronary syndromes. The precise placement of the 10 electrodes and faultless connection between the electrodes and the electrocardiograph are the basis for correct interpretation. However, ECG artifacts due to electrode cable misplacements do occur, and the error rate is particularly high in the intensive care unit (ICU). In two studies performed in a medical ICU, such artifacts occurred in 4.8% and 4.0%, respectively [1, 2]. This was significantly more than in the cardiology outpatient clinic, where only 0.4% of all ECGs showed signs of electrode cable misplacements [1]. We speculated that the frequency was significantly higher in the acute medical care setting for two reasons: First, ICU nurses had less experience and routine in recording ECGs than the specialized technicians in the cardiology outpatient clinic. Second, ICU staff suffered higher workload and more distraction during ECG recordings, both factors that generally increase the error rate in the ICU setting.

Electrode misplacements can lead to clinically important misdiagnosis of myocardial ischemia (Table 1) and provoke additional diagnostic tests or even unnecessary hospital admission. As current cardiology textbooks contain only little information on this issue, it is not surprising that physicians have difficulties in detecting artifacts caused by electrode cable switches. We showed an otherwise normal ECG with right arm–left leg electrode reversal (Fig. 1) to 29 physicians at our institutions. Electrode cable misplacement was suspected by only 45% of the doctors. However, supraventricular arrhythmias or cardiac ischemia were wrongly diagnosed by 28% and 31% of the doctors, respectively. In addition, the integrated ECG software is not helpful in diagnosing electrode misplacements and often suggests inappropriate conclusions instead [3]. Electrocardiographic errors due to switched electrode cables should be suspected when one or more of the following morphological changes occur [2–4]:

(a) In the peripheral leads:

- Abnormal P axis with positive P-wave in aVR and/or negative P-waves in lead I and/or II
- Very low (<0.1 mV) amplitude in lead I, II or III
- Abnormal QRS axis between −90° and −180°
- Concordant negative QRS and T-waves in leads I, II, III and/or I, aVL and/or aVF

(b) In the precordial leads:

- Abnormal R progression in leads V1 to V6 with an increase of the R-wave amplitude after an initial decrease in the precedent leads

ECG errors must be considered as preventable phenomena, which can be improved by using better technology and by education of ICU staff members [5]. An education program highlighting the importance of correct ECG recording and simple technical improvements with clearly visible labels on each electrode cable indicating the correct limbs led to a statistically significant error rate reduction by 75% [2]. However, ongoing efforts are needed to preserve, or even decrease, the frequency

Table 1 ECG changes due to electrode cable misplacement

Electrode cable reversal	ECG changes	Clinical interpretation
RA, LA	Negative P-wave in I, II. Positive P-wave in aVR. Concordant negative QRS- and T-waves in I, aVL	Old lateral infarction; atrial rhythm; dextrocardia with missing chest electrodes
RA, LL	Negative P-wave in II, III. Concordant negative QRS- and T-waves in II, III, aVF	Old inferior infarction; atrial rhythm
LA, LL	Q in III	Chronic inferior infarction
LA, RL	Low voltage in III	Electrode defect
RA, RL	Low voltage in II	Electrode defect
RL, LL	None	None

RA right arm, *RL* right leg, *LA* left arm, *LL* left leg

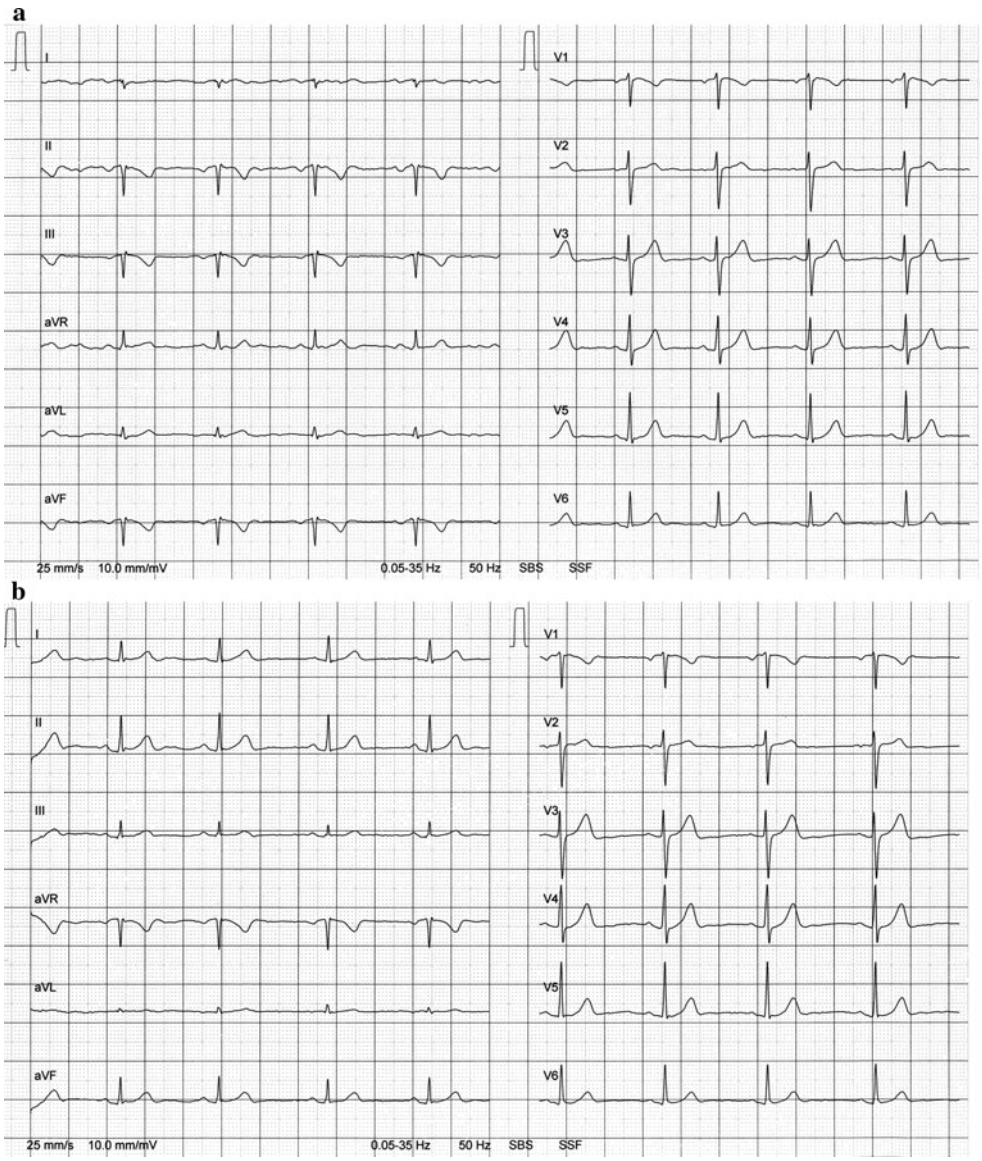

Fig. 1 **a** ECG of a healthy 35-year-old male with electrode cable reversal between the right arm and the left leg. The ECG shows an abnormal QRS axis between −90° and −120°, negative P-waves in II, III, and aVF, as well as concordant Q and negative T-waves in the inferior leads. Of note, the P-waves and QRS complexes are positive in aVR. **b** Control ECG from the same person with normal electrode cable positioning

of ECG artifacts due to electrode cable misplacements.

Acknowledgment Funded by Departmental funds.

Conflicts of interest None.

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T. Thaler
Department of Cardiology, Triemli City Hospital, Zurich, Switzerland

A. Rudiger (✉)
Medical Intensive Care Unit, University Hospital Zurich, Raemistrasse 100, 8091 Zurich, Switzerland
e-mail: alain.rudiger@usz.ch
Tel.: +41-44-2551111
Fax: +41-44-2553181